Supplementary Material: Mobile Mechatronic/ Robotic Orthotic Devices to Assist–Rehabilitate Neuromotor Impairments in the Upper Limb: A Systematic and Synthetic Review

APPENDIX 1 PEDRO INSPIRED SCORE FOR THE SELECTED ARTICLES – SORTED CHRONOLOGICALLY BY THEIR DATE OF PUBLICATION

No	Article	No of healthy subjects	No of patients	No of citations	Q1	Q2	Q3	Q4	PEDro score
1	Rocon et al. (2007)	0	10	203	5	5	5.0	3	9
2	Martinez et al. (2008)	1	0	30	3	2	0.3	2	4
3	Miller and Rosen (2010)	6	0	28	5	4	1.0	3	6
4	Yu and Rosen (2010)	0	0	47	5	1	1.5	5	6
5	Kim et al. (2012)	10	0	46	5	4	2.1	3	7
6	Huang et al. (2012)	11	22	21	5	5	0.4	2	6
7	Miller and Rosen (2010)	5	0	9	5	4	0.2	2	6
8	Pearce et al. (2012)	NA	NA	26	3	NA	1.2	5	6
9	Song et al. (2012)	1	0	11	5	2	0.2	3	5
10	Kim et al. (2013)	0	15	73	5	5	1.9	4	8
11	Lin et al. (2013a)	0	0	33	5	1	2.3	4	6
12	Guo et al. (2013)	0	0	13	5	1	1.2	2	5
13	Lin et al. (2013b)	0	0	0	5	1	0.5	1	4
14	Song et al. (2013)	1	0	2	5	2	0.6	4	6
15	Wei et al. (2013)	0	0	10	5	1	1.1	3	5
16	Noveanu et al. (2013)	NA	NA	4	5	NA	0.6	2	5
17	Giberti et al. (2014)	0	0	1	5	2	1.1	3	6
18	Song et al. (2014)	3	0	22	5	3	1.7	4	7
19	Dowling et al. (2014)	12	0	18	3	5	0.8	2	5
20	Xiao et al. (2014)	1	0	10	3	2	1.6	3	5
21	Andrikopoulos et al. (2015)	1	0	4	3	2	1.6	3	5
22	Nimawat and Jailiya (2015)	NA	NA	1	3	NA	1.5	2	4
23	Shull and Damian (2015)	NA	NA	38	5	NA	3.2	5	9
24	Nycz et al. (2015)	1	0	6	3	1	1.7	2	4
25	Kim and Rosen (2015)	10	0	7	5	4	2.1	5	8
26	Polygerinos et al. (2015)	1	0	214	5	2	5.0	5	9
27	Tageldeen et al. (2016)	0	0	1	3	1	2.1	3	5
28	Gao et al. (2016)	0	0	0	3	1	2.0	0	3
29	Nycz et al. (2016)	0	0	15	5	2	2.6	4	7

30	Guo et al. (2016)	0	0	0	5	1	2.0	3	6
31	Frisoli et al. (2016)	NA	NA	1	3	NA	2.1	3	5
32	Alavi et al. (2017)	1	0	0	5	2	2.5	4	7
33	Freer et al. (2017)	9	0	0	5	4	2.5	2	7
34	Gandolla et al. (2017)	3	0	0	3	3	2.5	2	5
35	Tu et al. (2017a)	3	0	0	5	3	2.5	4	7
36	Xiao et al. (2017)	0	0	0	5	1	2.5	2	5
37	Tu et al. (2017b)	1	0	0	5	2	2.5	4	7

Q1 – 5 points if indexed by Institute for Scientific Information (ISI) Thomson Reuters/ 3 points if indexed by other International Data Bases (IDB)

Q2 – number of citations per year pondered through the year of publication (described in section Methods of article's body text)

Q3* – number of human subjects included in the study, as follows:

No. of human subjects	Q3 score
0 healthy subjects/ 0 pacients	1
1 healthy subject/ 0 pacients	2
2–4 healthy subjects/ 1 – 2 pacients	3
5–10 healthy subjects/ 3 – 5 pacients	4
>10 healthy subjects/ >5 patients	5

Table S2. **Q3** score based on number of human subjects/ pacients

* This criterion does not apply to review articles: for such papers we considered the other three criteria, following the same calculation formula.

Q4 – the references' quality, as follows:

No. of references	Q4 score
0	0
1–10	1
11–20	2
21–30	3
31–40	4
$\geqslant 41$	5

Table S3. **Q4** score based on number of references

The total score of an article is obtained as the average of the points for each criterion multiplied by 2 (in order to range the maximal score up 10).

The PEDro inspired scoring primary data results have been statistically analyzed in table S4.

Modal Value	**5**
Average	**5.95**
Median	**6**
Dispersion	**1.81**
Standard deviation	**1.5**
Coefficient of variation	**25.23**
Pearson asymmetry coefficient	**0.63**

Table S4. Statistical analysis of the results

APPENDIX 2 MOBILE (WEARABLE AND/OR PORTABLE) PROTOTYPE DEVICES

Name and citation	Year	Brief description
The Motorized Upper-Limb Orthotic System (MULOS) (Johnson et al., 2001)	*2001*	*With 5 DOFs and attachable to a wheelchair, this prototype has multiple uses, including motorized assistance for severe disability, continuous passive motion and exercise device.*
Soft Robotic Exoskeleton (SRE) (Caldwell et al., 2007)	*2003*	*Weighing no more than 2 kg, this upper arm exoskeleton system has 7 DOFs by using rigid lightweight aluminium links combined with pneumatic muscle actuators.*
MAHI (Mechatronics and Haptic Interfaces lab) EXO-II (Gupta and O'Malley, 2006)	*2004*	*Having 4 active DOFs and 1 passive DOF, the robot is suitable for clinical usage by availing redundant safety measures, high accuracy quadrature encoders and reduced transmission rates. It is controlled by a computer running Simulink and Quark, thus reaching a command frequency of 1KHz.*
ASSIST (Sasaki et al., 2005)	*2005*	*Using two pneumatic soft actuators for palm and arm movement, this prototype targets elderly people/ those who need to be under care.*
Robotic Upper Extremity Repetitive Trainer/Therapy (RUPERT) IV (Kim et al., 2013; Tu et al., 2017a,b)	2005	RUPERT IV prototype has 5 actuated DOFs and uses iterative learning combined with a PID-based feedback controller in order to adapt to non-linear aspects generated by different patients performing various tasks.
Wearable Orthosis for Tremor Assessment and Suppression (WOTAS) (Rocon et al., 2007; Freer et al., 2017)	2007	Based on multiple types of sensors, including EMG, this prototype consists of a wearable orthosis designed to reduce tremor.
Muscle Assistant System (MAS) (Ding et al., 2008)	*2008*	*The prototype has a modular design combining posture measurement with muscle force estimation and power-assisting devices in a 4 DOFs structure. Unlike exoskeleton devices, the proposed prototype has no rigid frames and uses pneumatic actuators.*
Hybrid system (Varoto et al., 2008)	*2008*	*The elbow, wrist and hand prototype can be mounted on a wheelchair and is voice controlled directly by the patient*
Upper Extremity Exoskeleton (Moubarak et al., 2009)	*2009*	*Mounted on wheelchair, the proposed robot exoskeleton has 4 motorized DOFs commanded by a Dspace controller connected to Matlab/ Simulink using ControlDesk interface. In order to close the control loop, the device uses force sensors.*
Exoskeleton Robot (ExoRob) (Rahman et al., 2010)	2009	*A 2DOF wrist aluminium exoskeleton robot using DC motors that is worn on the lateral side and to help the pacient perform flexion/ extension*
NEUROExos (Vitiello et al., 2013)	2009	*This cable-driven elbow exoskeleton uses a remotely placed control unit equipped with two antagonist muscle-like hydraulic actuators*

Motion Assistive Exoskeleton-robot for Superior Extremity (ETS-MARSE) (Rahman et al., 2010)	*2010*	*Using a 7 DOFs exoskeleton, the proposed solution is controlled by using EMG signals in order to help patients in their daily routine.*
Upper-limb power-assist exoskeleton robot (Kiguchi et al., 2008)	*2010*	*Mounted on a wheelchair, the exoskeleton has 4-DOF power actuation and allows several rehabilitative motions such as: shoulder vertical/ horizontal flexion/ extension, elbow flexion/ extension and wrist supination/ pronation*
OrthoJacket (Schill et al., 2011)	*2010*	*Powered by hidraulic actuators, the "non-invasive modular hybrid neuro-orthosis" combines sensoritics with advanced signal processing techniques in order to identify patient intention and provide support*
euro Exos (Lenzi et al., 2011)	*2011*	*Includes a moving cylinder, micro compressor and controller. The torsion springs are mounted on the joints of each finger in order to provide assistive force. Each finger is driven by steel wire tendons which are supported by lightweight pulleys*
Upper limb's motion tracking exoskeleton device (Song and Guo, 2011)	*2011*	*Designed for home use, the 3 DOF exoskeleton device tracks the patient's movement by using an inertia sensor and is actuated by a DC motor.*
BMI-based occupational therapy assist suit (BOTAS) (Sakurada et al., 2013)	2013	*Even if it requires a computer connection in order to process the EEG signal, the device is fully wearable and uses a LED based system for signaling goal achievements (grasping and extension)*
Upper-limb exoskeleton rehabilitation device (ULERD) (Song et al., 2014)	2013	ULERD focuses on passive and resistance training by using 3 active DOFs and 4 passive DOFs controlled by a pulley system and three DC motors.
Wrist Gimbal (Martinez et al., 2013)	*2013*	*Using a simple arm rest with padding and straps, rubber hard stops on each axis and a simple design gives the 3 active DOFs exoskeleton prototype robustness and mechanical rigidity in a safe and practical manner for forearm and wrist rehabilitation.*
Upper limb exoskeleton (UL-EXO7) (Kim et al., 2013; Miller and Rosen, 2010; Yu and Rosen, 2010)	2013	This wearable 7 DOF Upper Limb Exoskeleton Robot uses a PID controlled articulation that enables a range-of-motion reaching 99%.
6DOF Robotic system (Noveanu et al., 2013)	2013	This 6DOF prototype introduces the usage of "smart fluids": electrorheological fluid (ERF) or magnetorheological fluid (MRF) for designing and implementing new robust braking systems.
Isolated Orthosis for Thumb Actuation (IOTA) (Aubin et al., 2013)	*2013*	*The prototype consistes of a 2 DOF thumb exoskeleton used in "pediatric at-home rehabilitation"*
Upper limb exoskeleton (Garrido et al., 2014)	*2014*	*The prototype has a modular structure and uses revolute joints in order to achieve the 4 DOFs required for arm rehabilitation*

6-DOF exoskeleton (Chen et al., 2014)	*2014*	*The prototype mechanism consists of multiple gear (straight and bevel) and support rings actuated through parallel joints in order to assist and analyze the patient's movement.*
Shoulder exoskeleton (Giberti et al., 2014)	2014	This hybrid structure characterized by a double parallel mechanism consists of a first platform fixed onto the body, near to the neck, a medium platform and a last platform. The actuators were chosen with a light weight in mind so that the whole system will not exceed 3 kg.
Soft robotic glove (Polygerinos et al., 2015)	2014	This orthotic device is actuated by using a hydraulic muscle like cylinders in order to perform several rehabilitation movements placed on a waist belt.
BCI-driven exoskeleton (Xiao et al., 2014)	2014	The 4 DOF exoskeleton is controlled by using a EEG based device (BCI) in order to assist the patient.
Wearable exoskeleton robotic hand/arm (Lee, 2014)	*2014*	*The 9 DOF robotic hand/arm exoskeleton is ultra light (300g) and combines electrical with mechanical (springs) actuators.*
Robotic Arm Orthosis (RAO) (Looned et al., 2014)	*2014*	*The system consists of a wearable hybrid prototype combining an elbow, wrist and hand robotic exoskeleton device with FES and BCI.*
Six-degrees-of-freedom upper-limb exoskeleton robot (6-REXOS) (Gunasekara et al., 2015)	*2015*	*The prototype focuses on improving the pHRI (physical human-robot interaction) by using 4 active rotational DOFs and 2 passive translational DOFs, thus ensuring movement redundancy and reduced misalignments.*
EXOskeletal WRIST (EXOWRIST) (Andrikopoulos et al., 2015)	2015	Involves pneumatic muscle actuators. This stands for the reliability and portability of robust robotic solutions for wrist rehabilitation. This approach enables two DOFs movements to be performed: extension/ flexion and ulnarradial deviation. It can be successfully integrated into a lot of rehabilitation exoskeletal concepts for the assisted movement of the upper limb
Soft glove and sleeve (Nycz et al., 2015)	2015	The prototype is constructed as a soft glove and sleeve that assists the patient's finger and elbow movements by using tendon-like actuated cables.
EMG-based upper limb exoskeleton (Tageldeen et al., 2016)	2016	The centerpiece of this prototype is a fuzzy controller based on torque estimation techniques. By providing an interactive gaming software environment, this prototype assists and engages patients in order to increase the rehabilitation efficiency.
Cable-driven upper limb exoskeleton (CABexo) (Xiao et al., 2017)	2017	The 6-DOF wearable system uses a complex structure of epicyclic gear trains controlled by cables.
BRIDGE exoskeleton (Gandolla et al., 2017)	2017	The light wearable exoskeleton has 5 DOFs controlled directly by the patient and is an extension of the passive MUNDUS exoskeleton that can be mounted on wheelchairs.

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